SBIR S2.05 Development

GSFC Optics Branch Technologies

Dr. Petar Arsenovic

Topic: S2: Advanced Telescope Systems

Subtopic: S2.05: Optics Manufacturing and Metrology for Telescope Optical Surfaces

Solicitation Development Objectives

Subtopics with science traceability and infusion potential

- Should articulate specific benefits for NASA missions and goals
- When possible, should trace to timely science mission requirements

Development tasks appropriate to small businesses

- No “critical path” deliverables or large, complex systems
- End product/capability should also provide a path to an attractive return on investment for small business

Planning for approximately three Phase 1 and one Phase 2 awards with superior infusion potential per Subtopic

- Topics that are too broad or too narrow may miss this goal
- Good proposals should get “cradle-to-grave” support from NASA

Subtopics will be prioritized according to these objectives. Subtopics that cannot meet these objectives may need to be reworked or dropped.

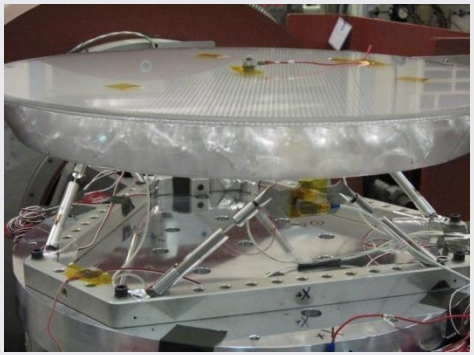
Optics Branch Key Technologies

Large Optics: The Optics Branch has developed specialized mirror mount designs for a highly light weighted primary mirror to maintain its position to the micron level without distorting it. The primary mirror is from ITT, and is a ULE fused silica ultra-lightweight sandwich mirror.

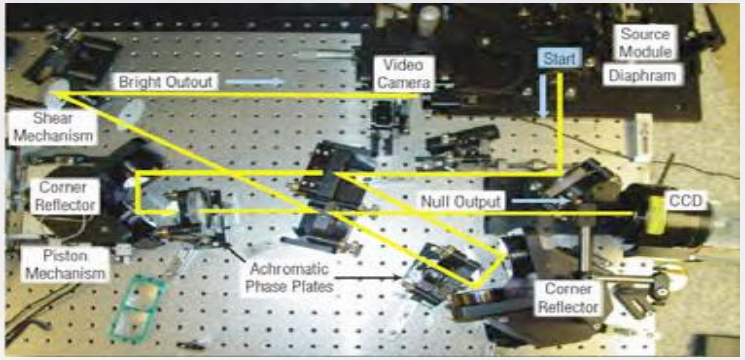
Visible Nulling Coronagraph Technology Development: The Extra Solar Planetary Imaging Coronagraph (EPIC) is a mission concept to directly detect and characterize extra-solar planets. The VNC is a critical technology to realize EPIC, and relies on nulling technology to separate starlight from planet light.

Wavefront Sensing: This technology supports a variety of optical characterization and control tasks that utilize image based optical wavefront sensing. Using the image based approach, optical sensing hardware is replaced by a computational approach where a digital camera serves as the wavefront sensor.

Development of an Ocean Radiometer for Carbon Assessment (ORCA) prototype: This recently funded IIP proposal is designed to meet the future measurement requirements of the NASA Ocean Biology and Bio-Geochemistry program. Funds are provided to build an ORCA prototype consisting of a rotating telescope assembly and an internal spectral calibrator subsystem.



Ultra-Lightweight Mirror



Visible Nulling Coronagraph Test Bed

GSFC Optics SBIR Success Stories

SBIR Optical Measuring Technique Applied to Projects:

Under the PY03 SBIR phase II project, Bauer Associates, Inc. of Wellesley, MA developed a working prototype instrument that utilizes a non-interferometric, optical technique for measuring absolute aspheric shape over the full surface of large mirrors to the nanometer level, without the need for known reference surfaces. Recently, Bauer worked with the Smithsonian Astrophysical Observatory to use the prototype to measure the surface of NASA's High- Resolution X-Ray Explorer (HIREX) Pathfinder mirror. COTR: Timo Saha (GSFC, 03/23/08)

Goddard Innovation Fund to Advance STTR Technology:
The Phase III to Trex Enterprises Corporation and University of Alabama at Huntsville is an extension of the PY03 STTR Phase II project entitled "High Volume, Low-Cost Production Process for High-grade Silicon Carbide Optics." The specific objective is to demonstrate corrective grinding and figuring of a SiC mandrel. This would enable the demonstration of x-ray mirror fabrication from a SiC mandrel and comparison of x-ray mirrors from a SiC mandrel and from a fused quartz mandrel. The targeted application is Constellation-X project. The Constellation-X Observatory is a combination of several X-ray telescopes working in unison to generate the observing power of one giant telescope. COTR: Dave Content. (GSFC, 06/22/08)

SBIR Mirror Concept Enables EPIC Mission Concept:
Advances in MEMS and control electronics technology based on a PY05 SBIR Phase II project with Iris AO, Inc. enable the scaling up of extreme-precision MEMS deformable mirrors for EPIC (Extrasolar Planet Imaging Coronagraph) concept. EPIC is a Discovery Mission concept designed to directly image and characterize extrasolar gas giant planets at typical distances of 2 to 20 AU from the parent star. COTR: Rick Lyon. (GSFC, 8/24/08)

S2.05 Subtopic Description

S2 Advanced Telescope Systems

S2.05 Optics Manufacturing and Metrology for Telescope Optical Surfaces

This subtopic focuses primarily on manufacturing and metrology of optical surfaces, especially for very small or very large and/or thin optics. Missions of interest include:

JDEM concepts (http://universe.nasa.gov/program/probes/jdem.html),
IXO (http://ixo.gsfc.nasa.gov/),
LISA (http://lisa.gsfc.nasa.gov/)
ICESAT (http://icesat.gsfc.nasa.gov/), CLARREO, and ACE

Optical systems currently being researched for these missions are large area aspheres, requiring accurate figuring and polishing across six orders of magnitude in period. Technologies are sought that will enhance the figure quality of optics in any range as long as the process does not introduce artifacts in other ranges. For example, mm-period polishing should not introduce waviness errors at the 20 mm or 0.05 mm periods in the power spectral density. Also, novel metrological solutions that can measure figure errors over a large fraction of the PSD range are sought, especially techniques and instrumentation that can perform measurements while the optic is mounted to the figuring/polishing machine.

Of particular interest is the area of x-ray optics metrology, including the evaluation of the optical quality of x-ray mirrors and substrates; the general characterization of x-ray mirrors; and the development of new metrology measurement techniques and instrumentation for x-ray mirrors.

S2.05 Subtopic Description

By the end of a Phase 2 program, technologies must be developed to the point where the technique or instrument can dovetail into an existing optics manufacturing facility producing optics at the R&D stage. Metrology instruments should have 10 nm or better surface height resolution and span at least 3 orders of magnitude in lateral spatial frequency.

Examples of technologies and instruments of interest include:

*Interferometric nulling optics for very shallow conical optics used in x-ray telescopes.
*Segmented systems commonly span 60 degrees in azimuth and 200 mm axial length and cone angles vary from 0.1 to 1 degree.
*Low stress metrology mounts that can hold very thin optics without introducing mounting distortion.
*Low normal force figuring/polishing systems operating in the 1 mm to 50 mm period range with minimal impact at significantly smaller and larger period ranges.
*In-situ metrology systems that can measure optics and provide feedback to figuring/polishing instruments without removing the part from the spindle.
*Innovative mirror substrate materials or manufacturing methods that produce thin mirror substrates that are stiffer and/or lighter than existing materials or methods.
*Extreme aspheric and/or anamorphic optics for pupil intensity amplitude apodization (PIAA).

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

SMD SBIR Proposed Technology Areas (S2.05)

Subtopic:	S2.05 Optics Manufacturing and Metrology for Telescope Optical Surfaces
Manager:	Petar Arsenovic, GSFC (Lead); Phil Stahl, MSFC (Participating); Eric Bloemhof, JPL (Participating)
Center(s):	Lead Center: GSFC, Participating Centers: MSFC, JPL

Optical systems are currently being researched that require accurate figuring and polishing across multiple orders of magnitude in period. Technologies are sought that will enhance the figure qualities of optics in any range, as long as the process does not introduce artifacts in other ranges.	**Science Traceability**	International X-ray Observatory (IXO), Joint Dark Energy Mission (JDEM)
	Need Horizon	Choose range: 1 to 3 years
	State of Art	Reduction or elimination of artifacts across multiple orders of magnitude in period.
	Importance	Importance relative to competitive solutions; choose rating, briefly explain (2) High – Highly desirable, competitors lacking in key areas
The high stresses introduced by conventional mirror coatings can cause large mirror substrate distortions that degrade telescope resolution. New low stress coatings and other technologies are needed to meet the imaging requirements of missions such as IXO.	**Science Traceability**	International X-ray Observatory (IXO)
	Need Horizon	Choose range: 1 to 3 years
	State of Art	Coatings can introduce distortions that are unacceptable for the very precise imaging requirements of future NASA x-ray missions.
	Importance	Importance relative to competitive solutions; choose rating, briefly explain (2) High – Highly desirable, competitors lacking in key areas
In-situ high speed scanning metrology options for both large optics and micro-optics are sought for performance and figure verification for space telescope systems.	**Science Traceability**	Laser Interferometer Space Antenna (LISA)
	Need Horizon	Choose range: 3 to 5 years
	State of Art	New technologies are needed for opposite ends of optics size range (large optics and micro-optics) with respect to high speed accurate scanning metrology.
	Importance	Importance relative to competitive solutions; choose rating, briefly explain (2) High – Highly desirable, competitors lacking in key areas

Phase 1: 8 Submitted 3 Funded

S2.05-8391 Reactive Atom Plasma Processing of Slumped Glass Wedges, RAPT Industries, Inc.

S2.05-9744 The Affordable Pre-Finishing of Silicon Carbide for Optical Applications, Creare, Inc.

S2.05-9745 Novel Materials for Mirror Substrate in Space Telescopes, Advanced Materials Technology, Inc.

Phase 2: 1 Funded

S2.05-9744 The Affordable Pre-Finishing of Silicon Carbide for Optical Applications, Creare, Inc.

Phase 1 13 Submitted 7 Funded

S2.05-8681 High Reflectivity, Broad-Band Silver Coating, Surface Optics Corporation

S2.05-8983 Low-Stress Iridium Coatings for Thin-Shell X-Ray Telescopes, Reflective X-ray Optics, LLC

S2.05-9001 Application of Zeeko's Novel Random Tool Path for Improvement of Surface PSD, Zeeko Technologies, LLC

S2.05-9323 Submicron Composite Mirror Replication, DR Technologies, Inc.

S2.05-9500 Super Polishing of Aluminum 6061-T6 Mirrors, Microengineered Metals, Inc.

S2.05-9876 High-Speed Scanning Interferometer Using CMOS Image Sensor and FPGA Based on Multi-Frequency Phase-Tracking Detection, Nanowave

S2.05-9938 RAP Figuring Slumped Mirrors to Remove Mid-Spatial Frequency Errors, RAPT Industries, Inc.

Phase 1 Highly Ranked Proposals

S2.05-8547 Rapid Mandrel Fabrication for X-ray Telescope

S2.05-8780 Coherent Laser Radar Metrology System for Large Scale Optical Systems

S2.05-9304 In-situ Metrology for the Corrective Polishing of Replicating Mandrels

S2.05-9809 Advanced Lightweight Metal Matrix Composite Segmented Optic Manufacture

Phase II funded

S2.05-9938 RAP Figuring Slumped Mirrors to Remove Mid-Spatial Frequency Errors

NASA SBIR/STTR Technologies

Rapid Mandrel Fabrication for X-ray Telescope

OptiPro Systems – Ontario, NY

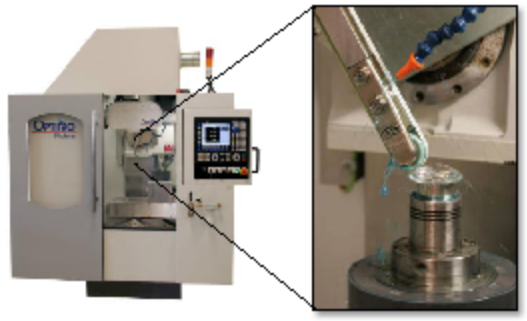
PI: Dr. Shai N. Shafrir

Proposal No.: 09-S2.05-8547

Identification and Significance of Innovation

UltraForm Finishing (UFF) is a novel sub-aperture polishing machine for polishing free-form and conformal optics. The UFF uses a continuous belt, providing relatively long working life, and a controlled repeatable and rapid material removal for a variety of optical materials. The UFF is a cost-effective polishing solution, capable of polishing optics from the ground state, removing grinding induced mid-spatial frequency and subsurface damage (SSD) without pre- or post-polishing.

TRL: beginning (3); end of contract (7)



Technical Objectives and Work Plan

Grinding of fused quartz tapered cylinder (mandrel)

Grinding machine parameters using OptiPro eSX 150 CNC machine

Pre-polishing corrections

Polishing the previously ground mandrel with OptiPro UltraForm Finishing (UFF) CNC polishing machine.

Develop algorithms to polish mandrel shape with raster tool paths.

Polishing experiments on the UFF will study how machine parameters, slurries, and pads affect the final surface figure and roughness.

Metrology using OpitPro UltraSurf Free-Form

Measure surface roughness of both ground and polished surfaces

Measurement of the ground/polished mandrel final shape

NASA and Non-NASA Applications

-Cylinders, non-tapered as well as tapered
-Aspheres
-Meter class optics, segmented optics, and off axis mirrors
-Extended UV optics (lithography)
-X- ray optics
-Conformal windows and domes
-Reconnaissance optical systems
-Commercial, e.g., Medical / Cinematography
-Injection mold inserts

Firm Contacts

Dr. Shai N. Shafrir
OptiPro Systems
6368 Dean Parkway, Ontario, NY 14519
Phone: 585-265-0160 x242; Fax: 585-265-9416

NASA SBIR/STTR Technologies

Coherent Laser Radar Metrology System for Large Scale Optical Systems

Pyxisvision Incorporated, Bristow, VA

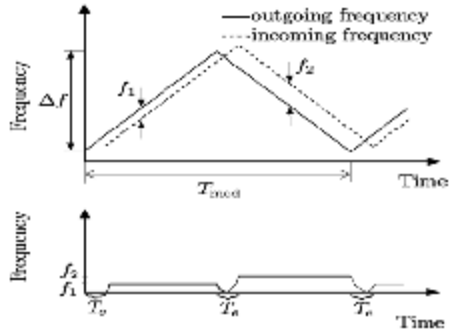
PI: Anthony Slotwinski

Proposal No.: S2.05- 8780

Identification and Significance of Innovation

A new type of laser radar metrology inspection system is proposed that incorporates a novel, dual laser coherent detection scheme capable of eliminating both environmental and scanner based Doppler ranging error. Due to the non-contact, stand-off nature of this technology, this system can measure optics and provide nearly real-time feedback to figuring/polishing instruments and, for advanced levels of integration and test, would allow fast, non-contact measurement of mirror rigid body alignment and prescription (i.e., radius, conic, aperture), with no special targets or references on the optic.

Estimated TRL (1 – 9) at beginning and end of contract: Beginning: 3, End: 4



Technical Objectives and Work Plan

Develop a prototype measurement system design with:
-Dual laser configuration for improve range accuracy
-Increase scanning angular accuracy
-Improved target detection algorithms

The work plan has the following tasks:
-Design and test a prototype dual laser ranging device
-Design ultra accurate scanner assembly
-Developing edge and hole detection algorithms

NASA and Non-NASA Applications

-Joint Dark Energy Mission (JDEM) telescope mirror fabrication and integration
-International X-ray Observatory (IXO) x-ray telescope mirror prescription and alignment measurement
-mm-wave antenna fabrication and assembly
-Aircraft and ship-building industry support
-Optical telescope assembly
-Optical instrument assembly

Firm Contacts:

Mr. Anthony Slotwinski, Pyxisvision Inc, 703-864-5901
Mr. Ghassan Chamsine, Pyxisvision Inc, 703-864-5901
Mr. Mina Rezk, Pyxisvision Inc, 703-864-5901

NASA SBIR/STTR Technologies

S2.05-9304 – In Situ Metrology for the Corrective Polishing of Replicating Mandrels

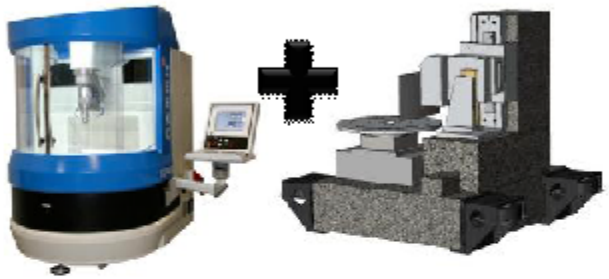
PI: John Kelchner

Zeeko Technologies, LLC – West Lafayette, IN

Identification and Significance of Innovation

In order to produce the number of mandrels needed for the International X-Ray Observatory (IXO) mission at the pace dictated by the project schedule, in situ metrology for manufacturing process control is an absolute necessity.

The proposed innovation will integrate a metrology system onto a corrective polisher. It will enable the timely, accurate, cost-effective manufacture of replicating mandrels for grazing-incidence optics.



Expected TRL Range at the end of Contract: 3-4

Technical Objectives and Work Plan

We will develop a solution for applying point-defined ultra-precision profilometry to the metrology of mandrel surfaces.

- Establish a detailed specification for the polishing and metrology systems.
- Develop conceptual designs including options for contact or non-contact sensors.
- Using error-budgeting methodologies supported by computer modeling and cost information, iterate on conceptual design alternatives to arrive at an optimal conceptual design.

Final design alternatives will be selected on several critical criteria: performance, manufacturing, and cost objectives.

NASA and Non-NASA Applications

In situ metrology applied to a deterministic polishing process will enable faster, cheaper, more accurate production of grazing-incidence mirrors.

NASA applications include:

- International X-Ray observatory (IXO)
- Nuclear Spectroscopic Telescope Array (NuSTAR)
- Wide-Field X-ray Telescope (WFXT)

Other applications include:

- the Advanced Gamma-ray Imaging System (AGIS)
- Cherenkov Telescope Array (CTA)

Zeeko Technologies, LLC, (765) 775-1010

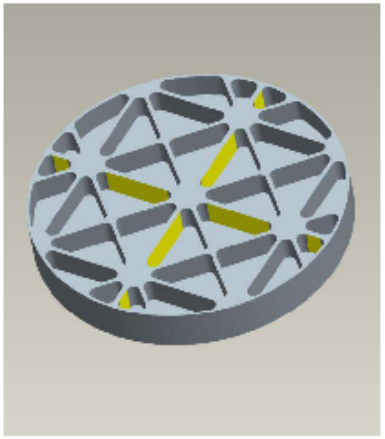
john.kelchner@zeekotechnologies.com

NASA SBIR/STTR TECHNOLOGIES

Advanced Lightweight Metal Matrix Composite Segmented Optic Manufacture

Hardric Laboratories, Inc. – North Chelmsford, MA
PI: Michael Kornik

Proposal: S2.05-9809

Identification and Significance of Innovation Segmented optics will allow the manufacture of larger optics with more design options, lower costs and accelerated lead times TRL: Start/2 ~~ Complete/5	
Technical Objectives and Work Plan To design, manufacture and test a subscale optic in the range of six inches in diameter, which demonstrates the technology to achieve larger segmented optics. The fabricated monolithic optic shall be tested, then cut into segments and fusion bonded to achieve a monolithic type of optic. The substrate shall be processed and comparison tested against the monolithic optic for performance differences.	**NASA and Non-NASA Applications** This type of segmented optic can potentially be used in any application requiring large scale mirrors where versatility, lower costs and shortened lead times are important. **Firm Contacts:** Michael Kornik x323 Roger Johnson x324 Vladimir Vudler x320

NON-PROPRIETARY DATA

In Conclusion

GSFC has a robust and productive SBIR program in the Optics area, with high quality proposals being submitted every year, leading to advances in key Optics Technologies. Companies with successful SBIR efforts have submitted high quality NTRs (New Technology Reports)